Fermilab

Particle Physics Division

Mechanical Department Engineering Note

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Title: DESI VERTICAL SUPPORT FIXTURE

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Abstract/Summary: Calculations to show conformance with AISC for fixtures used to support the entire DESI Corrector Barrel and each section into vertical position during the CMM activities.

Applicable Codes: AISC, AWS D1.1.2000

Givens:

DESI Barrel (2,700 lbs); AFTER SECTION (1,600 lbs); MIDDLE SECTION (390 lbs); FRONT SECTION (470 lbs); FPD SECTION (240 lbs).
Number of Support Points for each component (3)
Design Load per support pt: DESI Barrel (900 lbs); AFTER SECTION (540 lbs); MIDDLE SECTION (130 lbs); FRONT SECTION (160 lbs); FPD SECTION (80 lbs).

Desi Vertical Support Fixtures

The Vertical support fixtures include an assortment of fixtures used to support into the vertical orientation the DESI barrel and each section during the CMM activities.
The "Vert Barrel Assy CMM Fixture Layout" (F10046413) is used to support the DESI Barrel, see appendix 1; the "AFT Section CMM Fixture Layout Assy" (F10046306) is used to support the AFTER section, see appendix 2; the "CMM Fixture Layout Assy" (F10043467) is used to support the Middle Section, the Front Section and the FPD section, see appendix 3.
Each support fixture include a set of three foot anchored to a thick plate used as base on the CMM ground table. On the top side of two feet it is mounted a V-block used to constrain vertically and azimuthally the barrel/section while the third foot has a flat surface used to apply a vertical constraint only, see Figure 1.

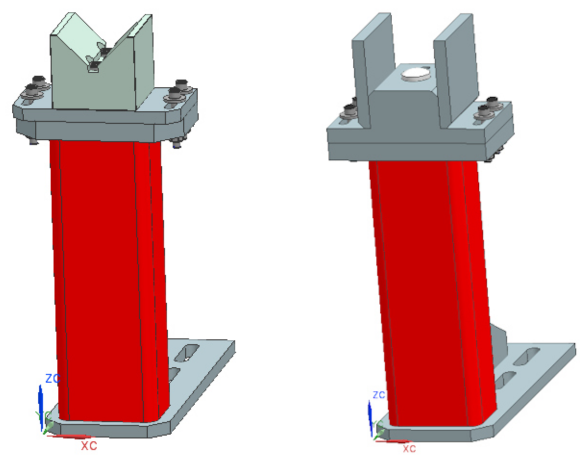

Figure.1 – Foot with V-Block (Left), Flat surface (Right)

The main structure include, see Figure 2:

(1) Column (Beam-1)
(2) #3 radial rods (Rod)
(3) Bolt Joint used to connect the rod to each support section point (Bolt Joint 1a-1b)
(4) Bolt Joints used to anchor the V-Block/Flat Surface to the top side of column (Bolt Joint 2)
(5) Bolt Joint used to anchor the feet to the base plate (Bolt Joint 3)
(6) Weld Joint used to join the top flange to the top side of the columns (Weld Joint 1)

(7) Weld Joint used to join the bottom flange and gussets to the bottom side of the feet.

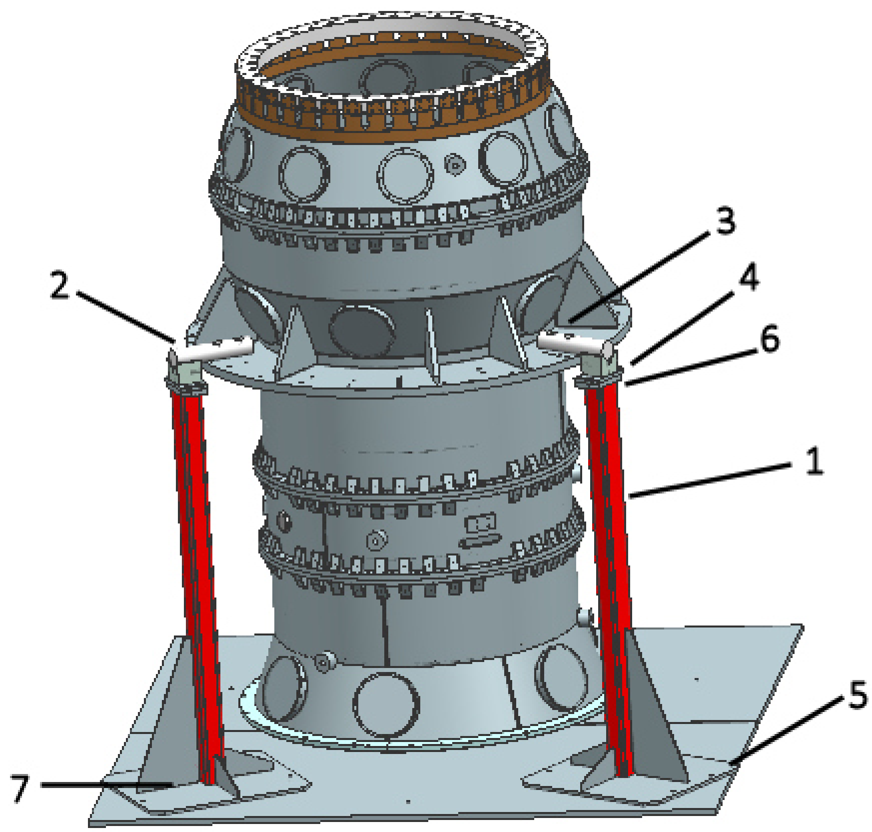

Figure.2 – List of Main structural components

(1) COLUMN "BEAM 1"

The BEAM 1 is a column used to support 1/3 of the weights of each section and/or entire barrel. On the worst case scenario the rectangular structural tubing 4"x3"x1/4" x 55" need to support 900 LBS.

According with the assembly drawing F10046413 the column can be considered in sidesway uninhibited condition where Ga=1.0 and Gb=10.0, see Figure 1 at page 3-5.

$K := 2$ K – factor

$L\_beam1 := 55in$ length of Beam 1

$r := 1.44in$ govening radius of gyration

$$\frac{K \cdot L\_beam1}{r} = 76.4$$

Since KL/r is less than Cc the allowable stress can be calculate with the formula given at page 5-19 Sec 1.5.1.3.1.

$E := 29000ksi$ Young Modulus of Beam 1

$Fy := 46000psi$ minimum yield tensile strength

$$Cc := \sqrt{\frac{2\pi^2 \cdot E}{Fy}} \qquad Cc = 111.6$$

$$Fa := \frac{\left[1 - \frac{\left(\frac{K \cdot L\_beam1}{r}\right)^2}{2 \cdot Cc^2}\right] \cdot Fy}{\frac{5}{3} + \left[\frac{3}{8 \cdot Cc} \cdot \left(\frac{K \cdot L\_beam1}{r}\right)\right] - \frac{\left(\frac{K \cdot L\_beam1}{r}\right)^3}{8 \cdot Cc^3}}$$

$Fa = 18.7 \times 10^3\,psi$ allowable stress for Beam 1

$A\_beam1 := 3.09in^2$ cross section of Beam 1

$$F\_beam1 := \frac{900}{A\_beam1}$$

$F\_beam1 \cdot in^2 = 291.3$ actual stress [psi]

The allowable stress for Beam 1 is greater than the actual stress so the Beam 1 is ok for the assembly drawing F10046413. On the assembly drawing F10046306-F10043467 the length of the column and the loads supported are smaller than the case analyzed so also those columns are ok.

(2) RADIAL RODS "ROD"

The radial cantelivered rods (1018 steel, hot rolled, tempered Fy=39,900psi) used on the assembly dwg F10046413-F10046306 are attached to two shoulder screws 3/4"-10 A307 on one side and they are sitting on the support feet to the other side.

On the cantelivered load condition the actual bending stress is:

$$L\_rod := 11in$$

$$d\_rod := 2.5in$$

$$F\_rod\_bending\_stress := \frac{900lbf \cdot L\_rod}{\left(\pi \cdot \frac{d\_rod^4}{64}\right)} \cdot \frac{d\_rod}{2}$$

$$F\_rod\_bending\_stress = 6.5 \times 10^3 psi$$ actual bending stress [psi]

$$Ft\_rod := 0.66 \cdot 39900psi$$ see page 5-20 section 1.5.1.4.1

$$Ft\_rod = 26.3 \times 10^3 psi$$ allowable bending stress

On the cantelivered condition the actual shear stress is:

$$F\_rod\_shear := \frac{900lbf}{\left(\pi \cdot \frac{d\_rod^2}{4}\right)}$$

$$F\_rod\_shear = 183.3 psi$$ actual shear stress [psi]

$$Fa\_shear := 0.4 \cdot 39900psi$$ see page 5-18 section 1.5.1.2.1

$$Fa\_shear = 16.0 \times 10^3 psi$$ allowable shear stress for rod

Both the allowable bending stress and the shear stress are greater than the actual stress the rods of assembly drawing F10046413 are ok. On the assembly drawing F10046306-F10043467 the loads are lighter so the rods are fine.

(3a) BOLT JOINT USED TO CONNECT THE RODS TO EACH SUPPORT SECTION POINT "BOLT JOINT 1a"

The bolts used to connect the rods to the After Section (F10046306) and to the Barrel (F10046413) are #2 Shoulder Bolts 3/4"-10 A307

To calculate the actual load a static analysis has been done on the cantelivered rod where the overall len(is 11 inches and the distance between the bolts located to one side of the rod is 3", see dwg #F10046299

$F\_bolt1 := 2400lbf$ actual force on the far end bolt

$F\_bolt2 := 3300lbf$ actual foce on the intermediated bolt

According with Table 1-A page 4-3 the allowable tension is 8800 lbs for 3/4-10 A307 bolts.

The actual tension force is smaller than the allowable tension so the bolt joint 1a is ok.

(3b) BOLT JOINT USED TO CONNECT THE RODS TO EACH SUPPORT SECTION POINT "BOLT JOINT 1b"

The rods used to support the Front Section, Middle Section and FPD section (see dwg #F10043467) have threads.

The actual bending stress and the shear stress are calculated into section 2.

$Fu\_1018\_steel := 68900psi$ ultimate tensile strength of 1018 hot rolled

$Fav := 0.17 \cdot Fu\_1018\_steel$

$Fav = 11.7 \times 10^3 psi$ allowable shear stress (Table 1.5.2.1)

According with Table 1.6.3 the allowable tension stress for bolts subjected to bending stress and shear stress is 0.43Fu-1.8fv <=0.33Fu

$Ft\_bolt\_joint\_1b := 0.43 \cdot Fu\_1018\_steel - (1.8 \cdot F\_rod\_shear)$

$Ft\_bolt\_joint\_1b = 29.3 \times 10^3 psi$ allowable tension stress [psi]

The actual tension stress 6.5 ksi is smaller than the allowable tension stress 29.3 ksi and the actual shear stress 0.183 ksi is smaller than the allowable shear stress 11.7 ksi so the thread on the rod is fine

(4) BOLT JOINT USED TO CONNECT THE V-Block/Flat SURFACE TO THE TOP END OF THE SUPPORT FOOT "BOLT JOINT 2"

The bolts used to connect the V-Block/Flat surface to the top end of the support foot are 5/16-18 Grade 5.

$A\_5\_16 := \frac{\pi}{4} \cdot \left(\frac{5}{16} \cdot in\right)^2$ gross area of 5/16-18 bolt

$ft\_5\_16 := \frac{900lb}{4}$

$ft\_5\_16 = 225.0\,lb$ actual tension/compression load on 5/16 bolt

$f\_at := 0.33 \cdot 120000psi \cdot A\_5\_16$

$f\_at = 3.0 \times 10^3\,lbf$ allowable tension force on each 5/16 grade 5 bolt

The allowable tension force is greater than the actual tension/compression force so the Bolt Joint 2 is ok

(5) BOLT JOINT USED TO CONNECT THE SUPPORT FOOT TO THE BASE PLATE "BOLT JOINT 3"

The bolts used to connect the support foot to the baseplate are1/2-13 Grade 5.

$A\_1\_2 := \frac{\pi}{4} \cdot \left(\frac{1}{2} \cdot in\right)^2$ gross area of 1/2-13 bolt

$ft\_1\_2 := \frac{900lb}{4}$

$ft\_5\_16 = 225.0\,lb$ actual tension/compression load on 5/16 bolt

$f\_at\_1\_2 := 0.33 \cdot 120000psi \cdot A\_1\_2$

$f\_at\_1\_2 = 7.8 \times 10^{3}\,lbf$ allowable tension force on each 1/2 grade 5 bolt

The allowable tension force of #4 bolts (31,200 lbs) is greater than the actual tension/compression 900 lb so the Bolt Joint 3 is ok.

(6) WELD JOINT USED TO JOIN THE TOP FLANGE TO THE TOP SIDE OF THE COLUMS "WELD JOINT 1" [AWS.D1.1.2000]

The weld joint is a fillet joint with 1/4" leg dimensions made using E7018 electrods, see dwg F10046411

$A\_weld\_1 := 0.25in \cdot .707 \cdot (4 + 3)in \cdot 2$

$\frac{A\_weld\_1}{in^{2}} = 2.5$ total area of weld joint 1 [in^2] , see page 4

According with formula used on 2.14.4 the allowable stress for the weld joint 1 is

$F\_E70 := 70000psi$ minimum specified strength of electrode

$thi := 9$ angle of loading measured from the weld

$Fv := 0.30 \cdot F\_E70 \cdot \left(1 + 0.5 \cdot \sin(thi)^{1.5}\right)$

$Fv = 23.8 \times 10^{3}\,psi$ allowable stress for the weld joint 1

$F\_weld\_1 := \frac{900lbf}{A\_weld\_1}$

$F\_weld\_1 = 363.7\,psi$ actual stress on the weld joint 1

The actual stress of the weld joint 1 is smaller than the allowable stress so the weld joint 1 is ok. Also th weld joint 2 will carry the same load with a larger weld joint area so the weld joint 2 is fine.

SEISMIC LOADING

During the parking/operation condition the vertical fixture might be subject to seismic loads so the following calculation will evaluate the resistant moment and the seismic load applied on the center-of-mass of DESI barrel (Mass=12.2kN - F1008150), see layout dwg of COM included on the Appendix.

$$M\_resistant := 12200N \cdot 813mm$$

$$\frac{M\_resistant}{kN \cdot m} = 9.9$$ resistant moment of mass

$$M\_seismic := 0.1 \cdot 12200N \cdot 1191mm$$

$$\frac{M\_seismic}{kN \cdot m} = 1.5$$ seismic moment of mass

The resistant moment of mass (9.9 kN-m) is greater than the seismic moment (1.5 kN-m) so the vertical fixture is fine.

The frame is not moved so there is only a seismic lateral load on the frame. Use 10% for the loading for this region.

$$Fseis := 0.1 \cdot 2700lbf$$

$$Fseis = 270.0\,lbf$$ seismic load

Check the lateral load perpendicular to the column "beam 1" (4"x3"x1/4"x55") assuming the load is applied on the top end of the column.

$$M := Fseis \cdot 55in$$ moment caused by seismic load

$$\sigma\_seismic := \frac{M}{4.1in^4} \cdot 1.5in$$

$$\sigma\_seismic = 5.4 \times 10^3\,psi$$ stress caused by seismic load

The stress caused by the seismic load (5.4ksi) is smaller than the allowable stress (25.4 ksi) so the column is able to resist to the bending from the seismic load.

APPENDIX:

F10046413---PDF1.pdf F10046306---PDF1.pdf F10043467---PDF1.pdf F10046306---PDF1.pdf F10046299---PDF1.pdf F10046411---PDF1.pdf

Layout dwg of COM.pdf